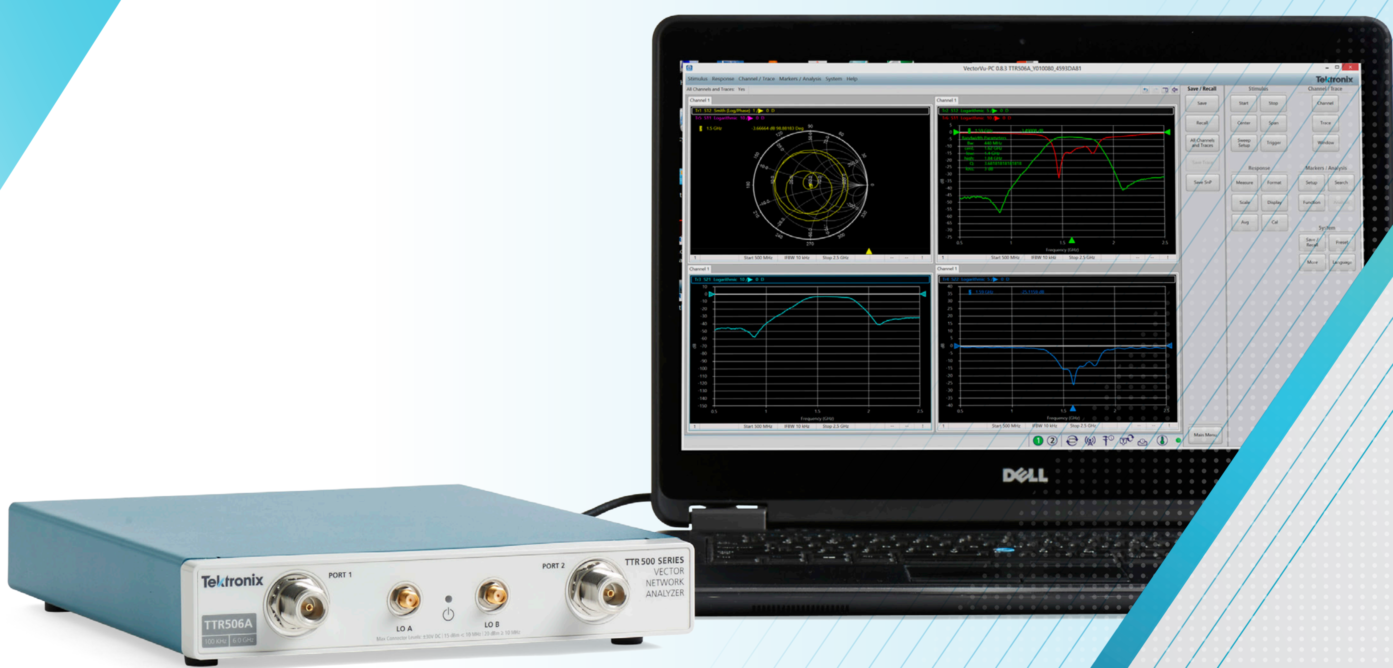
# Vector Network Analyzer Fundamentals

POSTER




Tektronix®

# Vector Network Analyzer Fundamentals

## Types of Measurement Error

WARNING: To reduce errors that affect measurement results, it is important to calibrate a VNA setup regularly. Calibration reduces the impact of systematic and drift errors.

### SYSTEMATIC ERROR

- Imperfections in the test equipment or in the test setup
- Typically predictable
- Can be easily factored out by a user calibration
- Examples that occur across the frequency range:
  - Output power variations
  - Ripples in the VNA receiver's frequency response
  - Power loss of RF cables that connect the DUT to the VNA

### RANDOM ERROR

- Error caused by noise emitted from the test equipment or test setup that varies with time
- Determines the degree of accuracy that can be achieved in your measurement
- Cannot be factored out by a user calibration
- Examples include:
  - Trace noise

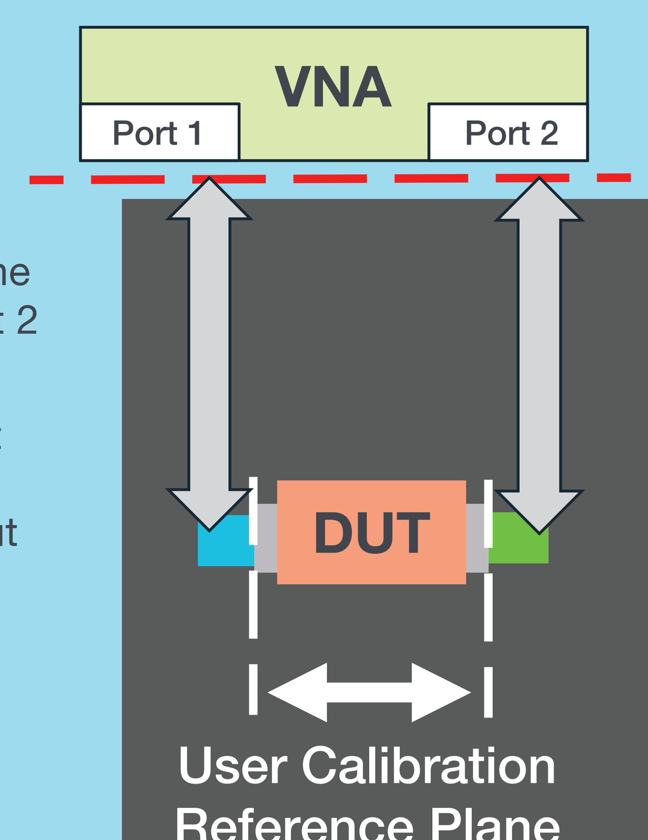
### DRIFT ERROR

- Measurement drift and variances that occur over time in test equipment and test setup after a user calibration
- The amount that the test setup drifts over time determines how often your test setup needs to be recalibrated
- Examples include:
  - Temperature changes
  - Humidity changes
  - Mechanical movement of the setup

## Understanding VNA Calibration

### Factory Calibration

- Covers up to the Port 1 and Port 2 connectors
- Ensures output signals meet specs and input signals will be represented accurately

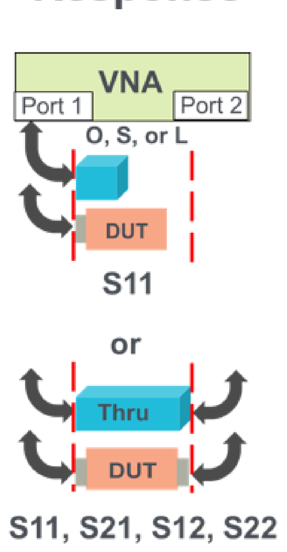



### User Calibration

- Factors out the effects of cables, adaptors, and most things used in the connection of the DUT
- Allows for exact measurement of the DUT performance alone

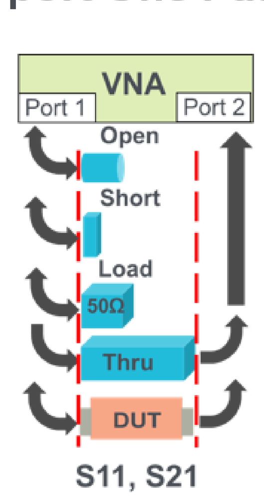
## Calibration Methods

### Response



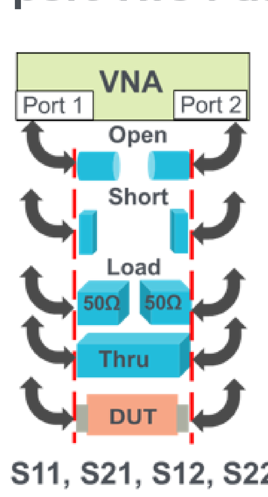

- Very simple
- Very few connections
- Less accurate
- Inexpensive

### 2-port One Path



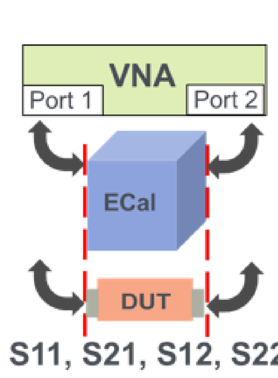

- Simple
- Few connections
- Moderately accurate
- Limited S-parameters

### 2-port Two Path




- Complex
- Many connections
- Highly accurate
- Full S-parameters

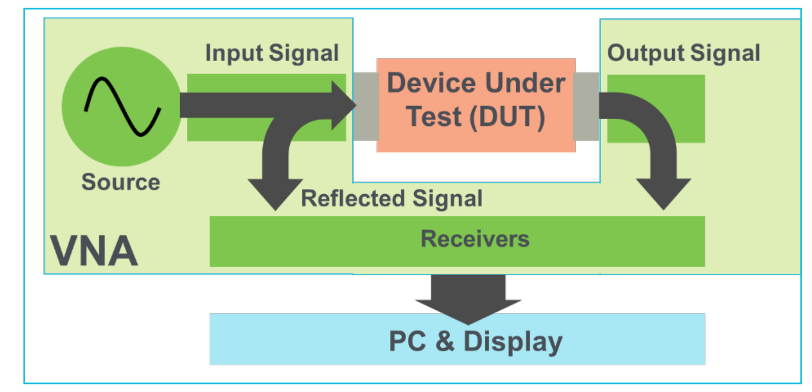
### Electronic




- Very simple
- Very few connections
- Highly accurate
- Expensive

## Basic VNA Operation

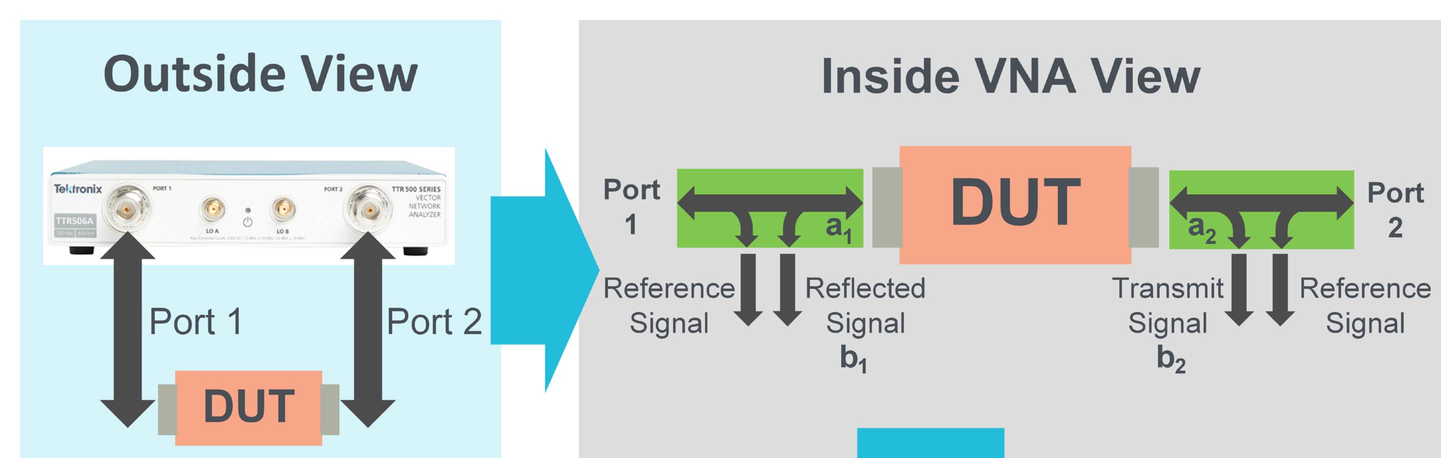
A VNA contains both a source, used to generate a known stimulus signal, and a set of receivers, used to determine changes to this stimulus caused by the device-under-test or DUT. This illustration highlights the basic operation of a VNA. For the sake of simplicity, it shows the source coming from Port 1, but most VNAs today are multipath instruments and can provide the stimulus signal to either port.

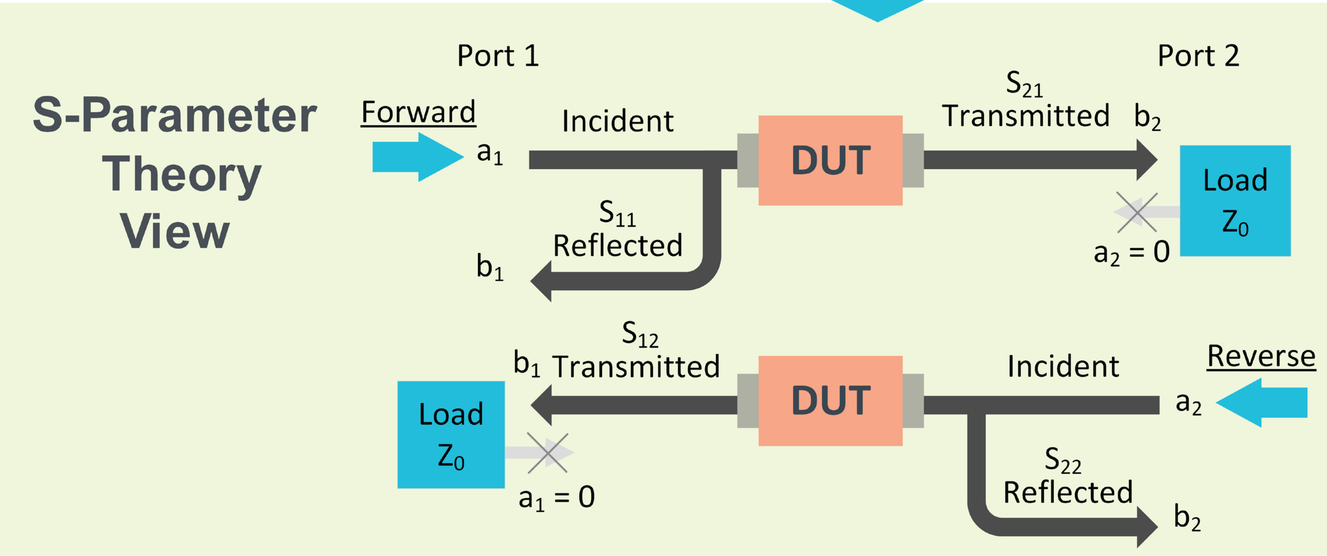



For simplicity, a single source is shown, but most VNAs today are multipath instruments and can provide the stimulus signal to either port.

## S-Parameter Basics

**S-Parameter Definition:** Scattering parameters or S-parameters describe the electrical properties and performance of RF electrical components or networks of components when undergoing various steady state electrical signal stimuli. They are unitless complex numbers, having both magnitude and phase, and are related to familiar measurements such as gain, loss, and reflection coefficient.

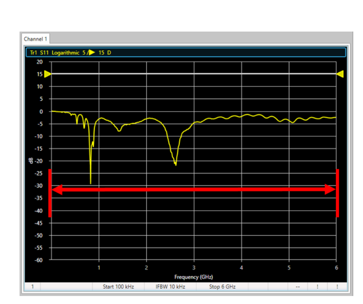


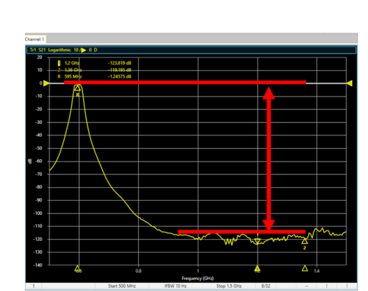

| | Forward: | Reverse: |
|---|---|---|
| Reflection: | $S_{11} = \frac{\text{Reflected}}{\text{Incident}} = \frac{b_1}{a_1}\Big\vert_{a_2=0}$ | $S_{22} = \frac{\text{Reflected}}{\text{Incident}} = \frac{b_2}{a_2}\Big\vert_{a_1=0}$ |
| Transmission: | $S_{21} = \frac{\text{Transmitted}}{\text{Incident}} = \frac{b_2}{a_1}\Big\vert_{a_2=0}$ | $S_{12} = \frac{\text{Transmitted}}{\text{Incident}} = \frac{b_1}{a_2}\Big\vert_{a_1=0}$ |

For more information on S-parameters go to tek.com/VNAprimer

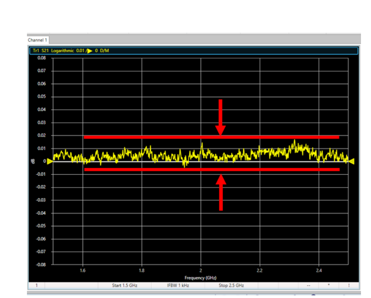
## Key VNA Parameters



**Frequency Range**
Consider not only your immediate needs but also potential future needs.



**Dynamic Range**
Make sure DUT noise floor is at least 10 dB above VNA spec.

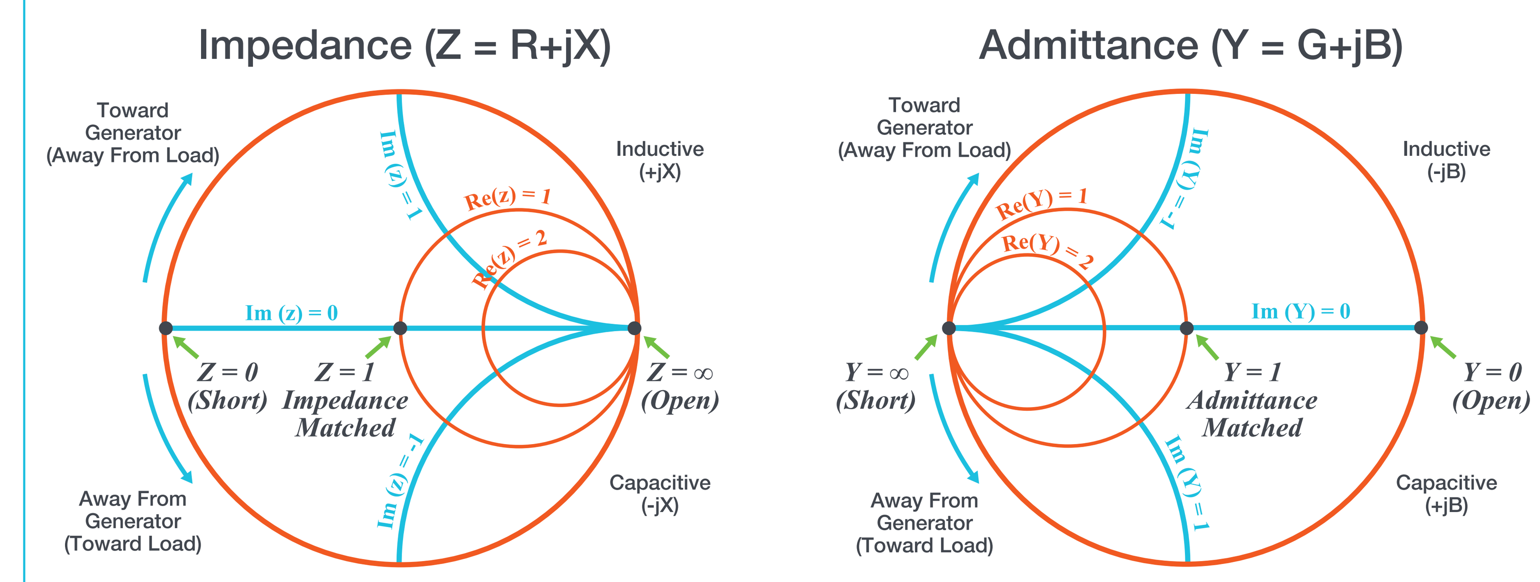


**Trace Noise**
Random noise generated by VNA that may affect measurement accuracy.

**Measurement Speed**
Critical for high volume manufacturing, less so for most other applications.

## Smith Chart 101

The Smith chart is a very useful tool used to determine complex impedances and admittances of RF circuits. Most network analyzers can automatically display the Smith chart, plot measured data on it, and provide adjustable markers to show the calculated impedance.




**Impedance Smith Chart**

1. The circles touching the right corner are constant-resistance circles.
2. The curves stretching from the right corner to the outer edges of the impedance Smith chart are constant-reactance curves.
3. The center of the circle is the Zo point. In most cases, Zo = 50 ohms. This is also the 20-millisiemens (mS) point.

**Admittance Smith Chart**

1. The circles in the Smith chart that touch the left corner are constant-conductance circles.
2. The curves stretching from the left corner of the Smith chart to the outer edges of the admittance Smith chart are constant-susceptance curves.

## Common S-Parameter Names

**S11** — Forward reflection coefficient
- Input return loss
- Input match
- VSWR

**S21** — Forward transmission coefficient
- Gain
- Loss

**S12** — Reverse transmission coefficient
- Reverse isolation

**S22** — Reverse reflection coefficient
- Output return loss
- Output match
- VSWR

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